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COST AND ECONOMIC IMPACT ANALYSIS OF THE PROPOSED NOx STANDARDS FOR SELECTED AIRCRAFT ENGINES

C.F. Day

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16. ABSTRACT

This report examines the impact of removing the 20,000 pound thrust threshold for commercial engine NOx standards promulgated in the draft NPRM. The study concludes that no 15-22,000 pound engines now in production or planned can meet the revised NOx standards and that the staged combustion technology used on larger engines will not lead to commercially acceptable low emission cannular engines. The new standard, if implemented for engines of this class, would stop production of the JT8 engine including its refanned versions with a subsequent significant adverse impact on Pratt and Whitney aircraft and aircraft producers. The lack of new JT8-powered, small transport aircraft would inhibit the ability of U.S. Airlines to serve small and medium sized communities.

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CHAPTER 1

INTRODUCTION

This report, prepared by J. Watson Noah, Inc. (JWN), is intended to supplement the economic impact analysis performed by Logistics Management Institute (LMI) and made a part of the record in their report entitled "The Economic Impact of Revised Gaseous Emission Regulations for Commercial Aircraft Engines" dated January, 1978. The LMI study was based on the draft NPRM, which included a 20,000 pound thrust threshold for the proposed 1984 standards. Subsequently, the NPRM was modified to eliminate the threshold, but at a date too late for LMI consideration.

The major issue concerning the threshold centers on the JT8 engine and its refanned 200 series derivative. There are more aircraft in the U.S. airline fleet which use the JT8 than all other types of aircraft combined. Moreover, in 1978, 316 aircraft using the standard JT8 and 27 aircraft using the refanned version were ordered from U.S. producers; this compares to 278 aircraft with other engines. Thus, the JT8 engine is the most popular commercial jet engine ever produced. The backlog of aircraft orders on hand insures that aircraft using the JT8 will be in production through the middle 1980s and perhaps beyond. In addition, the refanned version is being used on a newly developed entry into the short/medium haul market, the DC-9-80.

The Rolls-Royce Spey engine is also impacted by the elimination of the threshold. The engine is in limited production and is used on two available commercial aircraft (BAC-111 and F-28) and one general aviation jet (Gulf-Stream 2 and 3). There are no outstanding orders from U.S. airlines for either commercial transport and the Gulfstream application is exempt from the proposed regulations. The potential impact on the Spey is, therefore, not a major issue.

The major technical issue, as it was for larger engines, is the status of low NOx technology for the JT8. A Vorbix-type combustor was rig tested under NASA sponsorship and showed promise of reducing NOx emission. No engine tests were conducted and the NASA JT8 program was terminated. At best, therefore, a low NOx JT8 is well behind the larger engines in development and it is doubtful that a low NOx engine could be developed by 1984, even with a 100 percent success program.

There are no existing competitors to the JT8 in the 15-17 thousand pound thrust range. The 209 version, used on the DC-9-80, is rated at less than 20,000 pounds, but has growth potential well beyond. Douglas and several airlines are considering a growth version of the DC-9-80 that would utilize such an engine.

Once past 20,000 pounds, there is an alternative to the JT8 -- the CFM 56 currently rated at 22,000 pounds. Moreover, Rolls-Royce is considering the RB 432, an 18,000 pound engine still in the pre-development stage.

Because of the technological uncertainties, the analysis includes an examination of how aircraft powered by the JT8 are used by airlines; and it examines the potential market for current production aircraft. A largely qualitative economic analysis is included. Pratt and Whitney Aircraft, producer of the JT8, declined to supply cost estimates for use in this study. This decision, based on what the company perceived as good and sufficient reasons which need not be detailed here, made estimates of the cost-of-compliance virtually impossible with any degree of precision. JWN believes that the Vorbix technology cannot be applied to JT8-type engines and that an entirely new development program would be necessary to develop a low-NOx JT8. Because of the uncertainty of applicable technology, the chances of successful development, the time required, and the costs of implementation, JWN opted for a qualitative economic analysis.

Pending changes in noise regulations, brought about through regulatory action or legislation already introduced, could make the 1984 gaseous emission standards for JT8 engines a moot question. The proposals would require all newly manufactured aircraft, registered in the U.S., to meet Stage 3 noise standards, an apparent impossibility for current production JT8 aircraft. The DC-9-80 would, however, meet such standards. JWN has not considered potential changes in noise standards since this analysis is concerned with gaseous emissions.

CHAPTER 2

SUMMARY OF RESULTS AND CONCLUSIONS

UTILIZATION OF AND REQUIREMENT FOR SMALL TRANSPORTS

The majority of cities receiving jet airline service are and will continue to be highly dependent on JT8 aircraft. An analysis of CAB statistics on departures for the 12 months ending September 30, 1978 shows, for example, that 95 percent of all departures made by 707/DC-8 and larger aircraft occur at the 50 busiest airports. Conversely, jet operations at small airports (in terms of departures and passengers) are almost exclusively two-engined JT8 or Spey aircraft.

Many small airports receive a mixture of jet and turboprop service. The local service carriers (who operate all of the two-engine turboprops in airline service) are phasing the aircraft out of their inventory.

An analysis of more than 100 small to medium sized airports (50-400,000 passengers per year) showed that airlines tailor the aircraft used on a route to demand. Aircraft size (in terms of seats) decreased as passengers decreased and the ratio of passengers to seats-offered remained relatively constant except at airports with less than 100,000 annual passengers.

Trunk airlines dominate the industry in terms of passengers carried and passenger-miles produced. These airlines operated all of the large jets in passenger service until recently. Local service airlines operate small jet transports and turboprops and serve most of the small airports. Intrastate carriers, or at least the ones operating jets, use JT8 aircraft exclusively and aggressively exploit the short-haul markets they serve.

These distinctions are becoming somewhat blurred as a result of the Airline Deregulation Act of 1978. While fostering competition through ease of entry by qualified carriers into new markets, the Act guarantees service to cities now receiving service for the next ten years. Airlines, therefore, cannot abandon cities unless or until a replacement carrier is found. Subsidy support will be available if required.

The full impact of deregulation cannot be measured at this time but some of the cities in the JWN sample are receiving greatly reduced service (flight frequency). To date, those cities losing airline service have been added to the growing list of cities with commuter service only. It is unclear, however, that commuters provide a quality of service in terms of comfort, travel time and interline services that airlines provide. Thus, it is questionable that commuters, flying the types of aircraft available to them at this time, can serve as replacement carriers at all airports in the future.

Scheduled flights to a sample of large and small airports as shown in the August 1977 Official Airline Guide were analyzed to develop a frequency distribution of stage lengths flown by JT8 (and Spey) aircraft. When stage lengths were tabulated by hundred increments, the 727 was found to have a relatively uniform distribution of stage lengths from less than 100 miles up to about 800 miles. The distribution for two-engined aircraft was definitely skewed to the short stage lengths with both median and modal values of the distribution less than the mean.

The pattern of stage lengths, which can be expected to continue if smaller communities get jet service, indicates that aircraft cost per mile flown is an important determinant in assigning aircraft to small city routes. Cost per seat mile, which is controlling for high density routes, is an improper measure when the potential passenger loads will not produce breakeven load factors.

This reasoning explains, at least in part, why the airlies continue to order JT8 aircraft, even though these aircraft will have higher seat mile costs than the new generation of aircraft being offered. They will, of course, produce valuable revenues in the period before the new aircraft are available. No airline can, on the other hand, invest in an asset having a 15 to 20 year economic life merely to fill a short-term capacity requirement. It is apparent, therefore, that JT8 aircraft will be operating through the 1980s and into the 1990s.

COMPETITORS TO THE JT8

There are no competitive engines for the standard JT8 (in the 15-17 thousand pound range). Rolls-Royce is considering the RB 432, (18,000 pounds) but full-scale development has not been approved. A five-year program would be required after approval before the engine would be ready for use.

The CFM 56, currently rated at 22,000 pounds, is competitive with the JT8-200 series. The JT8-209 is rated at less than 20,000 pounds, but growth versions greater than 20,000 are being discussed.

The CFM 56, a modern high bypass ratio engine, is cleaner, quieter and more fuel efficient than the JT8-200 series. It also weighs more, has a larger diameter and is considerably more expensive, both to buy and to maintain. Choice between the two engines, on economic grounds, depends upon how these opposing factors are balanced for the particular application.

DC-8/707 RE-ENGINING

The CFM 56 seems to have won the competition for re-engining these four-engined aircraft. Noise regulations require that they be either modified to comply or phased out by 1985.

United Airlines recently announced its choice of the CFM 56 for re-engining some of its DC-8 Series 60 aircraft. Other operators who opt to re-engine are likely to follow suit because the development and certification costs associated with the engine change are too great to allow an alternative engine.

No 707 re-engining program has been announced. Boeing and CFM International will, however, certify a new 707 utilizing the engine. Thus, much of the hardware required for the engine-airframe match will have been developed. It seems unlikely, therefore, that operators choosing to re-engine the 707 would select the JT8-200 series engine.

POST 1984 MARKET FOR JT8 AIRCRAFT

A small but continuing market for current production JT8 aircraft (727, 737, DC-9) will exist in the period 1984 to 1990. A strong market for new technology, medium-haul transports is expected to exist. The JT8 powered DC-9-80 is an active candidate for the narrow body portion of this market.

Based on inputs from industry, JWN estimates that the potential market for current production aircraft in the U.S. is 10-12 aircraft per year. The market for new technology aircraft is about 85 aircraft per year. Both figures represent U.S. sales. Overseas sales could increase these totals significantly.

TECHNOLOGY ISSUES

JWN does not believe that any of the engines discussed will meet the 1984 standards. Although Vorbix-type combustors for the JT8 were rig-tested under NASA sponsorship, no engine tests were conducted and active development of a low NOx combustor was suspended. The rig tests of individual combustor cans (the JT8 is arranged in a ring around the engine core, hence the term can-annular engine) showed a significant reduction in NOx emissions. No engine tests (with a complete set of nine burner cans) were conducted, although originally scheduled because NASA believed that the market for JT8 engines would be very small by the time the Vorbix technology could be introduced. In our judgement, staged combustors of the type rig tested in the NASA JT8 program are not technically or economically feasible for a can-annular engine. The difficulties in matching the outputs of nine staged combustors with the input requirements of the engine turbine section are formidable. Moreover, the technology was far from proven in the NASA program because these are vast differences between engine components demonstrated in rigs tested and those that will be commercially acceptable in a production engine. A new development program based on other technologies might lead to a low NOx engine but the cost of such a program could make the engine too expensive for its potential market.

The CFM 56, although close, does not meet the 1984 standards and GE reported no technology on hand to reduce emissions further. Rolls-Royce is including a staged combustor in the RB 432 program. Based on the difficulties the producers are having with their larger engines, there is no guarantee that the engine will qualify.

ECONOMIC IMPACTS

There will be a continuing requirement for small, short/medium-haul transports after 1984. The airlines have a large inventory of such aircraft and limited replacements will be required between 1984-1990. The 1984 standards, applied to the JT8, would however:

- Eliminate the JT8 from production, resulting in a substantial adverse impact on Pratt and Whitney and on employment in the Connecticut Valley.
- Cause the DC-9-80 program to be terminated prematurely with the consequent loss of unrecovered development funds and competitive position to Douglas Aircraft Corporation.
- Increase the cost of serving small and medium communities and increase the subsidies required.
- Cause losses to aircraft producers through lost sales of current production aircraft. This coupled with the termination of the DC-9-80 program would have a serious adverse impact on Douglas, Long Beach.

CHAPTER 3

AIRLINE ENVIRONMENT FOR 1979 AND BEYOND

During 1978, airlines experienced continued growth in demand rivaling the rates achieved in the late 1960s. While margins declined as a result of partial deregulation, profits were excellent. New airplanes became available to the airlines when Boeing launched its first all new aircraft in more than a decade with the wide body 767 and the narrow body 757 series. The other U.S. producers were, along with Boeing, offering derivative versions of existing models including, of course, the previously launched DC-9-80. In Europe, the A 300 and A 310 programs were prospering and new aircraft such as the HS 146, JET 1 and JET were under consideration. Engine manufacturers had responded to these actual or potential new aircraft programs by proposing a variety of clipped fan derivatives of existing engines or all new engines such as the JT 10 and the RB 432.

Two factors have added uncertainties to predictions concerning the future. The first, the Airline Deregulation Act of 1978, is viewed variously as a threat or an opportunity for sustaining substantial growth. The second, escalating fuel price and potential shortages of fuel, clouds not only the economics of future operations, but also the very ability to capture the potential demand for air travel.

The Deregulation Act had the immediate effect of easing entry by qualified carriers into new markets and called for complete deregulation by 1983, when the regulatory functions of the CAB would cease. Some analysts view deregulation as a threat to airline stability since protected markets will be gone by 1983 or earlier. It seems clear that the intent of the Act is to foster competition and to encourage entry into new markets by both new and existing carriers. Other analysts view competition as an opportunity whereby the airlines can increase the efficiency of air transportation and provide service at even more attractive prices.

Ease of entry also implies ease of exit from existing markets. The Act provides protection to those smaller communities who have had, but might lose, air service. Such communities are guaranteed service over a ten-year period with some subsidy payments available. The full implications of the guaranteed service provisions are not clear at this time. To date, air carrier service has been replaced by commuter service. It is not clear, however, that such replacements reflect quality of service considerations, or that commuter substitution for carrier service will be acceptable for all future cases.

Fuel shortages will, of course, inhibit an airline's ability to exploit new market opportunities or to meet increasing demand in existing markets. Fuel price escalation may change the economics of aircraft-route structure pairings and alter the cost balance between old and new aircraft -- the new aircraft have definite fuel economy advantages on a seat-mile basis.

All of these factors -- surging demand, new aircraft and engine programs, deregulation and fuel problems -- affect the economic impacts associated with emission standards for commercial engines of less than 20,000 pounds thrust. The fact of the matter is that airlines have been ordering aircraft powered by JT8s in large numbers. Some, but by no means all, of these orders were placed to add capacity before next-generation aircraft are available. It is significant to note, however, that the United Airlines order which assured launching of the 767 program also included a substantial number (30) of 727 aircraft.

Boeing booked more firm orders for new aircraft in 1978 than any previous year -- a total of 480. This total included orders for 146 737 aircraft -- a single-year record -- and 131 727 aircraft. With these new orders and presently planned production rates, the 727 is sold out until 1981.

The boom in travel continues. Trunk airlines carried 13% more passengers in 1978 than in 1977, and passenger miles increased more than 14%. The increases for local service carriers were even higher -- 16% for passengers and 22% for passenger miles. Ton-miles produced by all-cargo carriers (Airlift Internation, Flying Tiger and Seaboard) increased by more than 23%, while the major intrastate carriers (Air California, Air Florida, PSA and Southwest) increased both passengers and passenger miles by more than 18%.

Trunk traffic in the first quarter of 1979 jumped 20% over the same quarter for 1978 -- a total of 8.3 billion additional passenger miles. This is more than double the predicted traffic increase and may reflect, at least in part, some initial effects of deregulation. It is, of course, difficult to judge with precision what the impact of deregulation will be. The various airlines seem to be adopting different approaches.

Some results are already apparent. All of the intrastate airlines are now offering interstate service -- the California-based carriers to Reno and Las Vegas, Texas-based Southwest to New Orleans, and Air Florida from several northeast cities to Florida points. World Airlines, a supplemental carrier, is offering low-priced, scheduled service between Washington and New York and the West Coast.

The distinction between trunks and local service carriers is becoming less clear as the local service carriers are flying longer stage lengths and offering more non-stop service between larger cities. Moreover, local service carriers are phasing out their two-engined turbo-prop (2ETP) aircraft and adding 727s to their fleets. The 2ETP total in the fleet dropped from 142 at the end of 1977 to 88 in 1978. A recent CAB fleet projection estimated that 40 would be in service at the end of 1981.

It is already evident that some small and medium-sized communities will lose air carrier service as a result of deregulation. Actual or planned cuts amount to at least 60 airports this year. None of these communities will be totally devoid of service, however, since the Deregulation Act requires that replacement carriers be found before all air carrier service can be terminated.

This discussion is intended to establish a proper context for evaluating the economic impacts of the proposal to include engines of less than 20,000 pound thrust among those covered by the amended oxides of nitrogen (NOx) standards. The potential post-1984 market for engines of this thrust range is a pivotal question. If there is not a market, then there is not economic impact or, for that matter, no reason to regulate emissions. If a market exists, its size is critical to determining the price increases resulting from the regulation since the cost of compliance must be amortized over the units sold. Moreover, the price increment, coupled with any changes in operating costs, becomes the basis for trade-off analyses between: (1) using a modified aircraft, (2) using a new aircraft type, or (3) extending the useful life of existing aircraft.

The discussion above indicates that aircraft powered by the JT8 engines (727, 737 and DC-9) will be operating through the 1990s. Orders and options on hand indicate that quantity production of these aircraft, in the absence of regulatory action to the contrary, will continue well into the 80s and perhaps beyond 1985. Furthermore, the refanned JT8-200 series is a critical component of the DC-9-80 derivative aircraft and may be used in other applications if amended noise rules are applied to new production of older aircraft types.

None of the newly launched or proposed U.S. aircraft are of the same size range as the twin-engined DC-9 and 737 aircraft; all are much larger. These new aircraft will be more efficient on high travel density routes where seat-mile costs are the controlling factor. At lower densities, however, cost per aircraft-mile may be the controlling factor.

Judged on today's operations, there are many of these lower density routes and several carriers (local service airlines) which are highly dependent upon them. Increasing demand and changes in route structure may alter this situation, but the problem of matching aircraft to routes and demand density must be addressed in this analysis.

CHAPTER 4

MARKET POTENTIAL FOR SHORT/MEDIUM-HAUL TRANSPORTS

The potential market for engines in the thrust range of interest to this study (15-22 thousand pounds) depends almost entirely on the market for narrow body, short/medium-haul transports. Moreover, these engines can hope to capture only a fraction of the total market -- continued production of current aircraft types and, possibly, newly developed aircraft of a size similar to current aircraft types. Larger, newly developed aircraft in the short/medium-haul class will probably utilize larger engines as has been done with the Boeing 757.

The CFM 56 engine has been selected for re-engining DC-8 and, perhaps, 707 aircraft as a result of the United Airline's decision. The general consensus is that the program is not large enough to support alternative engines. The United decision, plus the CFM International-Boeing program to certify a 707 with CFM 56 engines, seems to eliminate the JT8-200 series from the four-engine aircraft retrofit program.

Because the engines of interest have limited markets, the analysis must be carefully constructed. The question to be answered is not so much how many narrow body aircraft will be desired, but rather how many relatively small aircraft wil be needed. Further, the analysis should show the consequences to airlines and the public if the potential demand for small aircraft cannot be satisfied because of emission standards.

In order to answer these questions, it is necessary to understand the structure of airline service, airports served, and types of aircraft utilized. This chapter will provide both this type of background material and the post-1984 market potential for engines of interest.

AVIATION INDUSTRY STRUCTURE

Although more than 400 communities in the U.S. receive airline service, 75% of the aircraft operations (takeoffs and landings) and 80% of the passenger enplanements occur at the busiest 50 or so airports (about 14% of all airports served). Analysis of the latest available statistical data[1] shows that the concentration of large aircraft is even greater. Furthermore, an analysis of the Official Airline Guide (OAG) shows that almost all scheduled flights originate, transit, or terminate at one of these large airports.

Four classes of airports ranked according to the number of aircraft departures have been defined for this analysis. These are:

Class 1 - 50 or more departures per day. There were 55 airports in this class for 1978.

Class 2 - 20 to 49 departures per day. There were 55 airports in this class for 1978.

Class 3 - 5 to 19 departures per day. There were 130 airports in this class for 1978.

Class 4 - Less than 5 departures per day (exclusive of commuter service). There were 140 airports in this class which received at least some jet service.

Aircraft were also grouped in generic categories:

Four-Engine Wide Body (4 EWB) - 747

Three-Engine Wide Body (3 EWB) - DC-10, L1011

Two-Engine Wide Body (2 EWB) - A300

Four-Engine Regular Body (4 ERB) - DC-8, 707

Three-Engine Regular Body (3 ERB) - 727-100, 727-200

Two-Engine Regular Body (2 ERB) - 737, DC-9, BAC-111

Two-Engine Turboprop (2 ETP) - CV-580, CV-600, F-27, FH-227, YS-11

Table 1 shows 1978 departures by type for each class of airports. Note that 2 ETP were included because this type of aircraft makes up such a large percentage of departures at the smaller airports. The first thing to note is that more than 97% of all large airport activity (707

1/ Airport Activity Statistics of Certificated Route Air Carriers, Civil Aeronautics Board and Federal Aviation Agency, 12 months ending 30 September 1978.

TABLE 1

L ARTURES BY TYPE FROM EACH AIRPORT CLASS

12 MONTHS ENDING 30 SEPTEMBER 1978
(Thousands)

AIRPORT CLASS	TOTAL	4 EWB	3 EWB	2 EWB	4 ERB	3 ERB	2 ERB	2 ETP
Class 1	3,437.8	48.3	229.8	4.3	335.9	1,467.6	1,084.3	267.6
Class 2	565.2	0.2	3.0	0.4	10.4	223.2	269.5	58.5
Class 3	458.4	0.0	0.5	0.0	3.3	74.4	249.2	131.0
Class 4	123.9	0.0	0.0	0.0	0.0	3.5	37.4	83.0
TOTAL	4,585.3	48.5	233.3	4.7	349.6	1,768.7	1,640.4	540.1

PERCENT OF TOTAL

AIRPORT CLASS	TOTAL	4 EWB	3 EWB	2 EWB	4 ERB	3 ERB	2 ERB	2 ETP
Class 1	75.0%	99.6%	98.5%	91.3%	96.1%	83.0%	66.1%	49.5%
Class 2	12.3	0.4	1.3	8.7	3.0	12.6	16.4	10.8
Class 3	10.0	0.0	0.2	0.0	0.9	4.2	15.2	24.3
Class 4	2.7	0.0	0.0	0.0	0.0	0.2	2.3	15.4
TOTAL	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

NOTE: CAB certificated carriers only.

and larger) occurs at Class 1 airports and that the percentage of other aircraft type operations at Class 1 airports declines with size of aircraft. At smaller airports, Class 3 and 4, the reverse is true -- the percentage of operations increases as aircraft size decreases.

Passenger enplanements help explain these aircraft size and operations frequency relationships. Average enplanement of domestic passenger for each airport class were as follows for 1978:

<u>Class 1</u> - 3,592,000 enplanements

<u>Class 2</u> - 405,000 enplanements

<u>Class 3</u> - 123,000 enplanements

<u>Class 4</u> - 25,000 enplanements

In total, domestic trunk airlines carried 80% of the passengers, local service airlines about 20%. Table 2 shows the airlines included in the trunk and local service categories for this analysis. Such newly certificated, former commuter airlines as Air New England and Air Midwest are excluded, along with special carriers like Aspen, Wright or New York Airways.

83% of enplanements (for certificated carriers) occured at Class 1 airports while the remaining 17% were spread among the 55 Class 2 airports (9%), 130 Class 3 airports (7%) and 140 Class 4 airports (1%). Table 3 shows enplanements by carrier type and airport class for 1978. Trunk airlines board more than 87% of these passengers at Class 1 airports compared to 20% of the business from the 270 smaller airports as opposed to about 7.5% for trunks.

The relationship between departures, passengers and size of aircraft can be better understood from the information in Table 4 which shows passengers and seats per departure by class of airport along with the average number of seats for each aircraft type. The table shows that many of the Class 4 airports (which average only 2.4 departures and 41 passengers per day) can be efficiently served by commuter airlines with

TABLE 2

CARRIER BY CLASS

DOMESTIC TRUNKS	LOCAL SERVICE
American	Allegheny
Braniff	Frontier
Continental	Hughes
Delta	North Central
Eastern	Ozark
National	Piedmont
Northwest	Southern
TWA	Texas International
United	
Western	

TABLE

ENPLANEMENTS BY CARRIER T

1978

	ENPLANEMENTS (000)		
	TOTAL	TRUNKS	LOCAL
Class 1	3,592	3,021	571
Class 2	405	279	126
Class 3	123	60	63
Class 4	15	3	12

TABLE 4

PASSENGER AND SEAT DATA BY AIRPORT CLASS
1978

	AVERAGE ALL AIRPORTS	CLASS 1	CLASS 2	CLASS 3	CLASS 4
Departures per Day	33.06	171.2	28.15	9.66	2.42
Passengers per Day	1,716	9,840	1,110	337	41
Passengers per Departure	51.90	57.50	39.40	34.90	17.0
Seats per Departure	112.3	119.6	98.70	84.80	64.6
Passengers per Seat	.462	.480	.399	.412	.263

AVERAGE SEATS BY AIRCRAFT TYPE

4 EWB	357 Seats	4 ERB	150 Seats
3 EWB	246 Seats	3 ERB	118 Seats
2 EWB	229 Seats	2 ERB	92 Seats
		2 ETP	50 Seats

little degredation in quality of service. Many of the airports are presently served by commuters.

Class 2 and Class 3 airports are less efficient, in terms of passengers per seat, than Class 1 airports, but are relatively efficient from a profitability point of view. Since the average flight has approximately 18 passengers on board, these passenger-per-seat factors will yield acceptable load factors for the size aircraft utilized.

Size of aircraft is, of course, an important consideration. Many analysts believe that a positive relationship exists between flight frequency and travel demand. Certainly for short-haul flights such an assumption is reasonable since alternative forms of transportation are available. If, for example, only 120 seat aircraft were available, an 18% decrease in departures would be required to achieve the existing passenger-to-seats ratio. This could well result in decreased demand.

Appendix A contains data on a sample of more than 100 Class 2 and 3 airports ranging from 2,250 to 14,500 departures and from 60,000 to 380,000 enplanements. Of the 105 airports, 10 receive trunk service only, 33 receive local service only and 62 are served by both. Trunks serve 24 of the 25 airports with 250,000 or more passengers but of the 53 airports with less than 150,000 passengers, trunks serve only 23. Overall, trunk airlines carried 54% of the passengers but 70% of this total came from the top 25 airports.

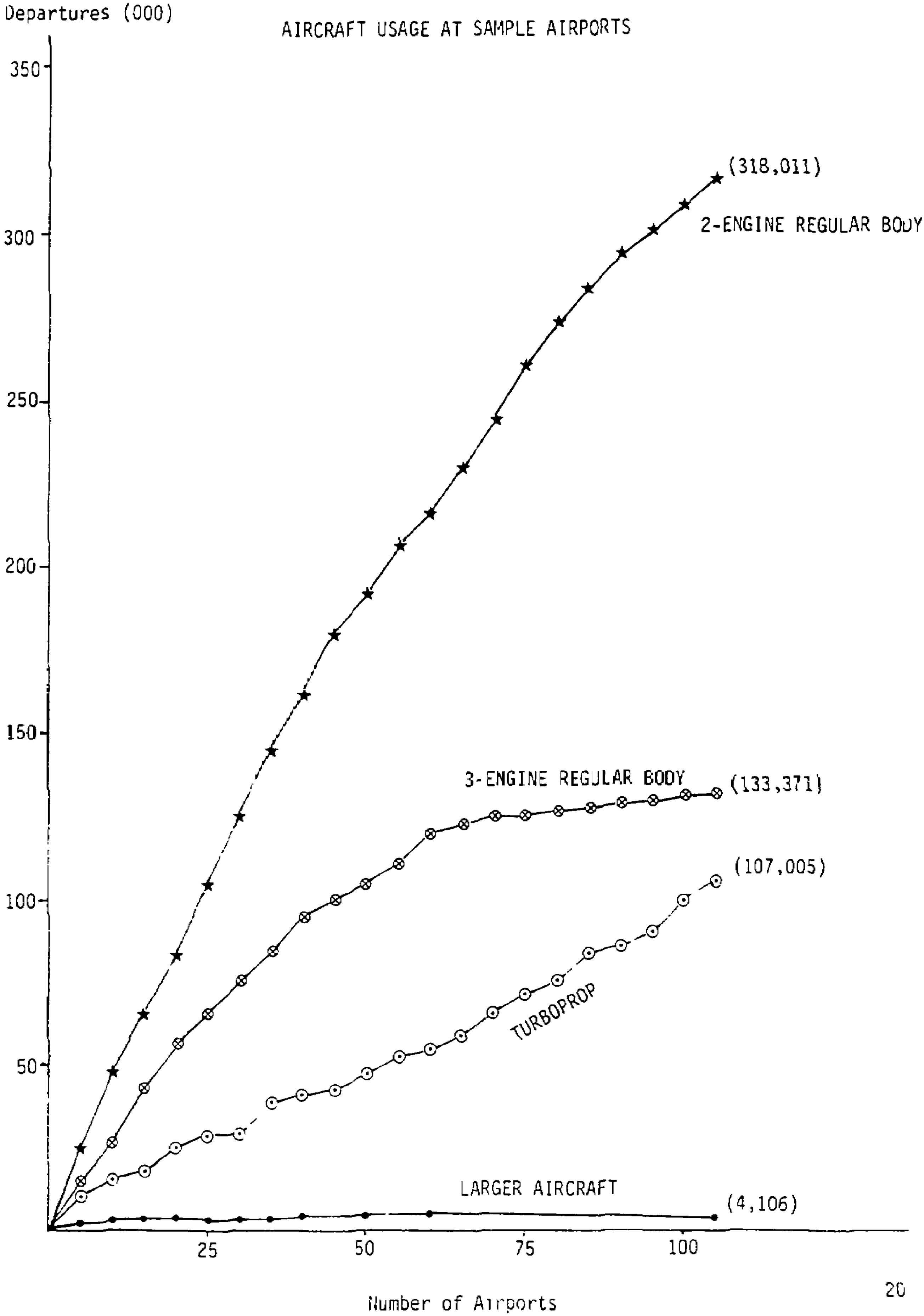
Figure 1 shows cumulative aircraft departures against airports arrayed in descending order of enplanements. There are a few large aircraft departures for a selected sample of airports including:

- Billings, Montana - 164 4 EWB, 143 3 EWB
- Great Falls, Montana - 3 4 EWB, 123 3 EWB, 78 4 ERB
- Mobile, Alabama - 1,415 4 ERB
- Daytona Beach, Florida - 386 3 EWB.

Large aircraft totalled less than 1% of all operations.

FIGURE 1

AIRCRAFT USAGE AT SAMPLE AIRPORTS



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Two-ERB were the most numerous aircraft used at sample airports totalling 56% of all departures. Three-ERB aircraft total 23% of operations but only a few of these operations were at airports with less than 150,000 passengers. The turboprops, which were 19% of the total, completed 36% of the departures at airports with less than 100,000 passengers.

Table 5 summarizes operations at the sample airports and illustrates that the carriers have matched aircraft and passengers quite consistently, except for small airports.

This analysis shows that air transportation to medium and small communities is highly dependent upon the availability of relatively small jet transports. Many of the Class 2 or 3 airports, even with substantial growth, are unlikely to generate traffic sufficient to support the use of large aircraft. In addition, physical limitations may be important. Average runway length, based on a 100% sample of airports by class provided by the FAA environmental data bank, are as follows:

- Class 1 - 9,200 feet
- Class 2 - 7,900 feet
- Class 3 - 6,650 feet
- Class 4 - 6,350 feet

FAA takeoff field length for various large aircraft are:

- 747-100 - 9,000 feet
- 747 SP - 7,800 feet
- DC-10-10 - 9,000 feet
- DC-10-30 - 10,500 feet
- L1011 - 7,960 feet
- DC-8-61 - 10,000 feet
- 707-300 - 10,000 feet

TABLE 5

OPERATIONS SUMMARY FOR SAMPLE AIRPORTS

RANGE (000)	NUMBER OF AIRPORTS	PASSENGERS PER DEPARTURE	SEATS PER DEPARTURE	PASSENGERS PER SEAT
350 or More	2	28.3	84.3	.34
300 - 349	11	40.5	98.0	.41
250 - 299	12	35.0	93.8	.37
200 - 249	13	34.6	92.2	.38
150 - 199	14	32.0	93.8	.34
100 - 149	26	29.4	86.9	.34
61 - 99	27	22.4	78.8	.28
AVERAGE		32.0	90.0	.36

which indicates that large aircraft could not operate (fully loaded) from many of the airports.

If present trends continue, service to small airports may become more difficult to provide. Local service airlines are phasing out turboprop aircraft with a high retirement rate. Their fleet contained 142 2 ETP aircraft at the end of 1977, but only 88 at the end of 1978. A recent fleet projection for 1981 prepared by the CAB estimates only 40 turboprop aircraft wuld be in service by the end of 1981.

STAGE LENGTHS FLOWN BY SMALL/MEDIUM TRANSPORTS

The discussion above centers on the types of airports which tend to be dependent upon smaller transport aircraft. The next step is to examine the stage lengths flown (miles between landings) by aircraft of these types.

The first step in the analysis was to select a sample of airports that would give a reasonable geographic and airline representation of the industry. The same included such large airports as Denver, medium sized Class 1 airports like Nashville and Class 2 airports like Mobile. Arrivals at each airport as shown in the Official Airline Guide (OAG) were examined and individual flight numbers of aircraft of interest (2 ERB and 3 ERB) were recorded (American flight 383, a 727-200 arrived from New York).

Next, each flight itinerary was recorded. AA 383, for example, originated in New York (LGA) and made the following stops: Nashville, Memphis, Los Angeles and San Francisco. Next, the route miles were recorded for each city pair[2/] and the stage lengths flown by each aircraft type were compiled.

The method used, including flight itineraries, means that at least some flights to all Class 1 and 2 airports were included in the sample and the concentration on all small aircraft helped insure that most Class 3 airports were represented. The average stage length for the sample

[2/] Book of Official CAB Airline Route Maps and Airport-to-Airport Mileages, Airline Tariff Publishing Company, Washington, D.C.

agreed quite closely with the average for the year as shown in the CAB, "Aircraft Operating Cost and Performance Report" for the year 1977.

Tables 6 and 7 show a breakdown of stage lengths flown in 100-mile increments for two-engine and three-engine aircraft respectively. Almost 60% of all 2 ERB flights are of less than 300 miles averaging about 160 miles. Some of the city pairs of less than 300 miles are high density routes capable of supporting wide body aircraft as they become available in quantity. New York and Washington or Boston, Dallas to Houston, and Chicago and Detroit are good examples. Other of these short stage length flights are made on low-density routes where the 100-seat aircraft is virtually essential. Piedmont Flight 68 is a good example. Flight 68 is a 737 operating over the following route: Norfolk, Richmond, Roanoke and Pittsburg.

The distribution of stage lengths flown by 2 ERB aircraft is definitely skewed by the preponderance of short stage lengths -- the average stage length is greater than the median and modal value. The distribution of 3 ERB stage lengths is relatively uniform up through 800 miles, which illustrates the versatility of the aircraft.

Deregulation should lead to a more uniform distribution of stage lengths for 2 ERB aircraft. The local service airlines have taken advantage of the relaxed market entry regulations and have added city pairs that offer both traffic density improvements and stage lengths better suited to the aircraft. Nevertheless, continued service to medium/small communities probably means that aircraft capable of economically flying relatively short stage lengths will be required.

POST-1984 MARKET

It is certain that the JT8 powered aircraft will be operating in large numbers during the last half of the 1980s and, perhaps, well into the 1990s. Orders already on hand insure that quantity production of these aircraft will continue into the early 1980s. It is not so clear that the demand for new aircraft of these types can be sustained into the post-1984 time period.

TABLE 6

BREAKDOWN OF STAGE LENGTHS FLOWN

TWO-ENGINE REGULAR BODY AIRCRAFT

YEAR 1977

STAGE LENGTH (MILES)	PERCENT OF TOTAL FLIGHTS TOTAL DOMESTIC	TRUNKS	LOCAL SERVICE	AVERAGE TRIP TOTAL DOMESTIC	TRUNKS	LOCAL SERVICE
0 - 99	14.5%	12.8%	15.9%	73	75	71
100 - 199	26.3	19.8	31.8	144	146	142
200 - 299	17.7	14.1	20.8	256	259	254
300 - 399	17.4	20.2	15.0	346	357	336
400 - 499	10.7	12.2	9.5	452	468	438
500 - 599	8.6	13.1	4.8	569	578	561
600 - 699	1.7	2.8	0.8	645	681	614
700 - 799	1.9	3.5	0.5	777	793	764
800 - 899	0.6	1.3	0.0	866	866	0
900 - 999	0.1	0.0	0.1	987	0	987
1000 and more	0.5	0.2	0.8	1034	1018	1047
	100.0%	100.0%	100.0%	289	340	246

TABLE 7

BREAKDOWN OF STAGE LENGTHS
727 - 100/200 AIRCRAFT
YEAR 1977

STAGE LENGTH (MILES)	PERCENT OF TOTAL		AVERAGE MILES	
	IN GROUP	CUMULATIVE	IN GROUP	CUMULATIVE
0 - 99	7.1%	7.1%	70	70
100 - 199	10.6	17.7	149	117
200 - 299	10.5	28.2	240	163
300 - 399	12.0	40.2	343	217
400 - 499	8.7	48.9	447	258
500 - 599	11.8	60.7	541	313
600 - 699	9.0	69.7	639	355
700 - 799	11.6	81.3	742	410
800 - 899	5.6	86.9	838	438
900 - 999	4.7	91.6	934	464
1000 - 1500	7.3	98.9	1227	520
1500 and More	1.1	100.0	1572	532

The existing fleet as of 31 December 1978 is shown in Table 8. These aircraft make up a substantial portion of the total airline fleet and will carry a significant portion of total passengers well into the future. An unpublished CAB projection, for example, estimated that these small and medium aircraft would deliver 46% of total passenger miles in 1981.

The Air Transport Association (ATA) furnished JWN a fleet projection through 1985 based on a June 1978 survey of its members. The ATA fleet excludes the intrastate carriers shown above, but includes both Air Canada and CP Air. The ATA projection is shown in Table 9 while Table 10 shows additions to and retirements from the ATA for the years covered (1979-85).

The ATA projection forecasts the addition of 12 to 15 new small/medium aircraft each year for 1982 to 1985. A survey of 59 North American and Caribbean Airlines, conducted by Douglas Aircraft and furnished to JWN, indicates a potential market of 8-10 aircraft of this type per year after 1984, excluding the DC-9-80. The same survey indicated a market average of about 85 aircraft per year for new technology, short/medium range aircraft including the DC-9-80.

The ATA and Douglas projections indicate a small but continuing market for aircraft of interest - no more than 10 to 12 per year. Adding the DC-9-80 could easily double the market for JT8 aircraft.

TABLE 8

SMALL/MEDIUM TRANSPORT FLEET
12 DECEMBER 1978

	727	2 ERB	737	DC-9	BAC-111
TRUNKS	863	227	81	146	0
LOCAL SERVICE	14	288	49	209	30
INTRASTATE	32	27	22	5	0
ALASKA/HAWAII	10	24	15	9	0
TOTAL	919	566	167	369	30

SOURCE: World Aviation Directory, Summer 1979

TABLE 9

ESTIMATED AIRCRAFT IN FLEET AT YEAR END

ATA MEMBERS ONLY

JUNE 1978 SURVEY

	1977	1978	1979	1980	1981	1982	1983	1984	1985
BAC-111	31	30	30	29	28	28	28	28	28
DC-9-10	82	81	80	80	80	80	80	80	80
DC-9-30	249	247	259	268	271	274	278	279	284
DC-9-50	34	42	48	48	51	53	55	55	55
DC-9-80	0	0	0	2	4	8	8	8	8
B-737-100	1	0	0	0	0	0	0	0	0
B-737-200	140	149	162	163	165	159	173	178	180
B-727-100	377	358	338	324	315	300	276	236	214
B-727-200	472	553	614	671	695	697	699	702	705

TABLE 10

RETIREMENTS AND ADDITIONS TO FLEET

ATA MEMBERS ONLY

JUNE 1978 SURVEY

	DC-9-10		DC-9-30		DC-9-50		B-737		B-727		TOTAL	
	RET	ADD	RET	ADD	RET	ADD	RET	ADD	RET	ADD	RET	ADD
1979	1	0	0	12	0	6	1	14	20	61	22	93
1980	0	0	1	10	0	0	1	2	14	57	16	69
1981	0	0	3	6	0	3	1	3	9	24	13	36
1982	0	0	0	3	0	2	1	5	15	2	16	12
1983	0	0	1	5	0	2	1	5	24	2	26	14
1984	0	0	3	4	0	0	3	8	40	3	46	15
1985	0	0	2	7	0	0	0	2	22	3	24	12
TOTAL	1	0	10	47	0	13	8	39	144	152	163	251

RET = Retirements

ADD = Additions

CHAPTER 5

LOW NOx ENGINES IN THE 15-22 THOUSAND POUND THRUST RANGE

At the present time, there is only one production engine available in the 20,000 pound range - the JT8. Production versions of the CFM 56, rated at 22,000 pounds, are not yet available and the RB 432 is still largely a paper engine.

Barring regulatory action to the contrary, the CFM 56 will soon be available. United Airlines has committed to re-engine 30 DC-8-61 transports with the CFM 56 at a cost of about $1,400 million. The package includes 150 engines - one spare for each aircraft set of four. Delta, Flying Tiger, and Braniff are reportedly considering retrofit of the DC-8 Series 60 aircraft. The worldwide total of Series 60 transports is about 240, 180 of which are -61 and -63 aircraft. These are prime candidates for retrofit because they can carry about 250 passengers. CFM International estimates that 150 DC-8s could be re-engined by the end of 1984.

The engine is also due to be certified on a 707 late this year. While none of these aircraft have been ordered by any airline to date, the certification process makes a 707 re-engining program more attractive. Although reportedly under consideration, no such program has been announced.

Full scale development of the RB 432 has not yet been approved. Design and component development is continuing and an engine size in the 18,000 pound range is contemplated. The development decision probably hinges on an attractive aircraft program which could utilize such an engine.

The Rolls-Royce Spey, rated at less than 15,000 pounds and therefore not directly comparable to the other engines discussed here, will continue in production at a low rate for the time period of interest. Its main U.S. application will be the Gulfstream 2 and 3 business jet, a non-commercial aircraft exempt from these standards. It will be used on commercial aircraft still in production, the BAC-111 and the F-28, although there are no known U.S. orders for such aircraft.

POTENTIAL NEW AIRCRAFT PROGRAMS

There are several new aircraft programs either in development or in the planning phase that would utilize engines of the class considered here. The DC-9-80 program has been launched and about 80 orders are on the books. First deliveries are scheduled for 1980. Press sources report that Boeing is considering a twin engined version of the 727, smaller than the 757. Such an aircraft would not use one of the announced versions of the JT8, (209 or 217) but, if built, could use another derivative. The CFM 56 seems the most logical choice of existing engines.

There are several European programs of interest. The HS 146 is in development. This aircraft, a high winged, 4-engined transport with 70 to 100 seats, is designed as a feeder jet for short-haul, low density routes. The Lycoming ALF 502H, rated at 6,700 pounds, will power the aircraft. The HS 146 is included in this study because it is a potential candidate for the post 1984 short-haul market. The ALF 502 is not, strictly speaking, an alternative to the JT8. It remains to be seen if the assumed economic advantages of the 4-engine design prove out in practice.

The Joint European Transport (JET) program is still under consideration. JET-1 is planned for 136 seats, JET-2 for 163. Both versions would use the CFM 56. A largely undefined JET-3 is being considered using a growth version of the CFM 56 rated at 25-27,000 pounds. Fokker is considering the F-29, a somewhat larger version of the F-28 designed for short-haul/low-density applications. It would use a new engine, presumably the RB 432.

With the possible exception of the F-29 program, none of these aircraft are likely to lead to new engine programs.

LOW NOx POTENTIAL OF CANDIDATE ENGINES

It seems unlikely to JWN that any of the engines discussed here will meet the 1984 NOx standards. The JT8 has high emissions compared to the CFM 56, but the CFM 56 in its planned configuration, will not meet the

1984 levels. Low NOx will be a design parameter in RB 432 combustion design, but it is not certain that the engine, if developed, will meet the standard.

JT8 Development Work - Rig tests of several configurations of combustors were included in the NASA sponsored reduced emission program. A Vorbix-type staged combustor was included and tests showed a significant reduction in NOx. The research program was terminated before any engine tests were conducted.

Although the rig tests could be termed successful since significant reductions in NOx were obtained, it is the judgement of JWN that a Vorbix-type combustor is impractical for a can-annular engine. There are several reasons for this opinion. First, all engine producers have experienced difficulties in matching staged combustor outputs with turbine input requirements during low NOx development on their larger engines. This problem cannot help but be more difficult when the turbine receives inputs from 9 separate combustion chambers. Second, the design of the JT8 burner-can tested required that fuel injection tubes be used to supply the main sector. These tubes, although outside the combustor itself, are located in the hostile environment of the annulus and subjected to high temperatures. Experience with the large engines indicated that fuel purging from injection nozzles is probably required to prevent the build-up of carbon deposits. Such purging would probably be required for a JT8 Vorbix application with the added problem of what to do with the extremely hot fuel in the injection tube. A very complex fuel management system would be required for the Vorbix JT8.

These problems are difficult and essentially demonstrate that the application of staged combustors to can-annular engines is unproven and perhaps impossible. On this basis, an entirely new development program, probably based upon new concepts, will be required. The cost and time required for such a program will be significant and perhaps approach those expended for low NOx development for larger engines.

RR Spey - This engine, like the JT8, is a can-annular type. Rolls-Royce, perhaps because of the limited U.S. commercial market, has not attempted to develop a low NOx Spey. They report, however, that water injection appears to be the only technically feasible way to reduce NOx emissions. All parties argue that water injection is an unacceptable solution.

CFM 56 - The CFM 56 is a relatively low NOx engine but it does not meet the proposed standards. Furthermore, as of Fall, 1978, GE had no technology on hand that would reduce NOx without increasing other emissions to unacceptable levels.

RB 432 - Combustor design for this engine has considered emission standards as design parameters. A scaled-up RB 401 annular vaporizer combustor will marginally meet HC/CO standards, but not NOx. A scaled-down RB 211-524 combustor gives predicted emission values that might meet CO and NOx standards, but not HC. Staging increases combustor length by more than 2 inches and would increase engine weight by about 150 pounds. The engine would suffer the same durability and maintainability problems as other staged combustor engines. The requirement to meet NOx standards can be expected to increase both development cost and time. A five-year program from go-ahead to entry into service is anticipated.

CHAPTER 6

POTENTIAL ECONOMIC IMPACTS

Quantifying the economic impacts associated with environmental regulations is a difficult task at best, especially for an industry facing such significant changes as the air transportation industry. Ordinarily, however, estimates with a reasonable degree of validity can be developed, provided sufficient background data can be accumulated to evaluate the major time-technology-cost issues raised by the regulatory proposal. These conditions could not be met in this case because one of the major companies concerned, Pratt and Whitney, declined to participate for what the company believed were good and sufficient reasons.

JWN respects the Pratt and Whitney decision and no criticism is intended in this statement of fact. Their decision did, however, alter the nature of the impact analysis. JWN could not, without substantial assistance from Pratt and Whitney, develop a valid estimate of the cost of compliance. Although several models are available for estimating aircraft engine costs, none are suitable for this analysis. The models, in general, are based on such performance characteristics as thrust, turbine inlet temperature, compression ratio or bypass ratios. None of these parameters should change in the transition to a low NOx engine. Quite the contrary, a successful low NOx development must insure no significant changes in performance parameters.

The normal analytic procedure -- estimate the cost of compliance, then translate these costs into impacts on such interested parties as producers, aircraft manufacturers, airlines, travelers, and the public -- could not be applied. Instead, alternative measures were used to develop largely qualitative measures.

As discussed above, JWN does not believe that a low NOx version of the JT8 engine is technically or economically feasible, particularly by 1984. It seems clear to us that a Vorbix-type application is infeasible for a can-annular engine. While it is possible that a new development program could lead to a low NOx engine, the development cost and time would probably erode any economic potential of the basic engine or its refanned derivatives. Similarly, we know of no programs underway at General Electric that would allow the CFM 56 to meet the standard. The RB 432 has not been approved for full scale development and would require a five-year development cycle after go-ahead.

JWN concludes that promulgation of the NOx standards as proposed would essentially eliminate new production of existing or planned engines in the 15-22,000 pound class. The long-term effects of such an action are almost impossible to quantify. On the one hand, there are more than 1,500 aircraft using this type of engine that will require replacement during the last decade of the century. On the other hand, if a significant demand for engines of this size exists, it seems reasonable to assume that an environmentally acceptable engine can and will be developed. Fuel supply problems and potential alternative fuels may lead to significantly different power plants in that time period.

The short-term effects could be severe, impacting all segments of the industry -- producers, airlines and travelers. The DC-8 and potential 707 re-engining programs would be disrupted and, perhaps, cost the airline industry the post-1984 use of economically viable aircraft in both primary and secondary uses. Potential sales of current production aircraft (10-12 aircraft per year through 1990) would be lost. The DC-9-80 program would have to be terminated with a substantial loss to the producer in terms of unrecovered aircraft development costs and market position. The impact on Pratt and Whitney would be significant since the JT8, although perhaps phasing down, would still be making a substantial contribution to the cost flow and profits. Loss of these revenues would hamper other engine development programs.

JWN believes, therefore, that the proposed standards are neither technically nor economically feasible. The CFM 56 could meet a somewhat relaxed set of standards. We have assumed, therefore, that such a standard should be investigated on the grounds of reasonableness. Since we know of no technology that will reduce JT8 NOx emissions significantly, the JT8 could qualify only if, essentially, no standard at all were applied.

Elimination of the JT8 only for its emissions would have adverse impacts on the industry and travelers. The DC-9-80 program would, essentially, be terminated. Douglas considered the CFM 56 during the development program, but concluded that the CFM 56 aircraft would cost approximately $3 million more (22%) and require approximately 25 more seats to achieve competitive seat mile costs. The JT8-209 aircraft was designed for field lengths comparable to the 30 series, which could not necessarily be obtained with the CFM 56. The size and weight of the CFM 56 would require additional development for new nacelles and pylons, beef-up and changes to the aft fuselage (engine mount adapter and higher skin thickness) and modifications to the air conditioning system because of higher bleed air temperatures. These changes in size and cost would make the aircraft less attractive to many potential customers, in Douglas' view, and the extra time required to develop the CFM 56 aircraft would eliminate an important market advantage -- the availability of the DC-9-80 well ahead of potential competition.

Airlines would be deprived of desirable aircraft -- perhaps 50 or more current production types and the DC-9-80 share of the new aircraft market. The airlines could abandon service to additional small/medium cities, buy substitute aircraft or retain older aircraft in the fleet for a longer period. Some cost is associated with each of these alternatives.

Pratt and Whitney would suffer the adverse impacts discussed above. The impact on Douglas would be substantial. Boeing would also be impacted through lost sales at a time when major capital expenditures for new aircraft development had not yet been recovered.

Airline cost per mile for the small city-short haul market will almost certainly be increased by the elimination of the JT8. The 757 compares favorably with the 727 on a cost per seat mile basis and reportedly will consume 9% less fuel over a 400 mile stage length. Maintenance costs for two RB 211-535 engines will be substantially higher than the costs for three JT8 engines on the 727. These costs will more than offset the fuel savings at today's prices. The difference would be greater if the RB 211 has the staged combustor necessary to meet 1984 standards. Fuel price increases in the amount likely to occur by 1984 may offset this maintenance cost differential. Two ERB aircraft, however, burn approximately 35% less fuel per block-hour than the 727-200 and experience 25% less maintenance costs. It does not appear, therefore, that the 757 can compare to these aircraft on a cost-per-mile basis even with significant fuel price increases.

Figure 2, based on information supplied by Boeing for another study and interpreted by JWN for application here, illustrates the differences discussed above. Note that the plot labeled 737-200 is analogous to any 2 ERB and that the plot labeled JT8 REFAN stretch is analogous to the DC-9-80. The figure illustrates that 2 ERB aircraft are preferred on low density routes by a wide margin (in terms of per mile cost). The annual penalty for using a 757 (assuming a fixed passenger load) on such a route is approximately $3.7 milliion.

The increases in costs for the small city-short haul market, resulting either from substitute aircraft or extended life aircraft, should not have a major impact on fares. Increased costs will have an impact on airline profitability and most of the burden will fall on local service carriers. All of these carriers, except Allegheny, receive subsidy payments.

Based on the discussion above, 1984 standards -- which would eliminate the JT8 engine -- would have the following adverse impacts:

1. A substantial impact on Pratt and Whitney in terms of cash flow, profits and, perhaps, employment.

2. A substantial impact on Douglas in terms of unrecouped development costs for the DC-9-80, lost sales of a potentially profitable aircraft line, and a diminished competitive capacity.

3. A reduction in the number of small/medium cities receiving airline class service or increased subsidy payments to local service carriers. It is possible that both would occur.

APPENDIX A

105 AIRPORT SAMPLE DATA

TABLE A-1

105 AIRPORT SAMPLE

ENPLANEMENTS AND DEPARTURES BY TYPE

	ENPLANE-MENTS (000)	DEPARTURES BY AIRCRAFT TYPE									
			WIDE BODY			REGULAR BODY			TURBOPROP		
		TOTAL	4 ENG	3 ENG	2 ENG	4 ENG	3 ENG	2 ENG	4 ENG	2 ENG	OTHER
ROANOKE	380	14,506	0	0	0	0	2,707	5,348	0	6,451	0
MADISON	354	11,461	0	0	0	0	2,937	6,719	0	1,805	0
SAVANNAH	338	5,198	0	0	0	1,415	3,772	11	0	0	0
MOBILE	336	10,474	0	0	0	0	2,448	8,026	0	0	0
MOLINE	331	10,663	0	0	0	24	3,361	5,258	0	2,020	0
TOLEDO	331	7,698	0	0	0	15	3,831	3,849	0	3	0
GREENVILLE	324	8,373	0	0	0	0	2,753	4,656	0	964	0
GREEN BAY	321	10,891	0	0	0	0	0	7,748	0	3,143	0
LEXINGTON	319	8,270	0	0	0	0	2,353	4,772	0	1,145	0
DAYTONA BEACH	317	5,748	0	386	0	0	3,013	2,349	0	0	0
FORT MEYERS	310	4,753	0	0	0	0	4,249	504	0	0	0
HARRISBURGH	309	5,909	0	2	0	237	979	2,932	0	10	1,749
CHATTANOOGA	303	9,493	0	0	0	6	3,900	5,587	0	0	0
AKRON-CANTON	289	7,592	0	0	0	4	1,734	5,837	0	17	0
COLORADO SPRINGS	286	7,724	0	14	0	5	4,756	571	0	2,378	0
AMARILLO	286	7,643	1	0	0	8	4,347	2,606	0	681	0
BILLINGS	282	7,969	164	143	0	0	2,414	3,352	0	716	1,180
ALLENTOWN	273	5,120	0	0	0	0	2,684	2,424	1	8	3
HUNTSVILLE	272	8,377	0	0	0	5	2,065	6,301	0	0	6
SOUIX FALLS	271	11,516	0	1	0	355	1,539	3,670	0	5,951	0
CHARLESTON, W. VA.	267	8,224	0	0	0	5	1,599	4,446	0	2,174	0
PEORIA	266	10,065	0	0	0	0	1,167	7,692	0	1,206	0
CEDAR RAPIDS	257	7,797	0	0	0	13	2,260	4,528	0	996	0
MONTEREY	253	4,730	0	0	0	13	1,838	2,879	0	0	0
FORT WAYNE	250	6,141	0	0	0	20	2,767	3,354	0	0	0

TABLE A-1 (Continued)

	ENPLANE-MENTS (000)	DEPARTURES BY AIRCRAFT TYPE									
		TOTAL	WIDE BODY			REGULAR BODY			TURBOPROP		OTHER
			4 ENG	3 ENG	2 ENG	4 ENG	3 ENG	2 ENG	4 ENG	2 ENG	
BATON ROUGE	245	7,455	0	0	0	0	2,914	4,541	0	0	0
EVANSVILLE	244	5,723	0	0	0	0	1,046	4,677	0	0	0
TALLAHASSEE	237	6,576	0	0	0	45	1,534	5,042	0	0	0
MONTGOMERY	234	7,452	0	0	0	0	2,601	1,756	0	0	0
PORTLAND	232	5,936	0	0	0	2	2,801	1,532	0	761	840
SOUTH BEND	226	6,242	0	0	0	18	1,760	2,784	0	1,680	0
BRISTOL/TRI CITIES	224	9,621	0	0	0	0	1,026	5,411	0	2,614	570
SAGINAW	222	5,828	0	0	0	16	1,288	3,794	0	730	0
LINCOLN	220	9,232	0	0	0	12	2,231	4,262	0	2,727	0
LANSING	218	8,320	0	0	0	14	1,149	2,788	0	2,369	0
CORPUS CHRISTI	203	3,583	0	0	0	0	2,178	1,399	0	6	0
EUGENE	203	4,612	0	0	0	0	13	4,596	0	3	0
AUSTIN	193	9,941	0	0	0	0	6,123	3,816	0	2	0
PALM SPRINGS	188	3,355	0	17	0	711	1,246	1,381	0	0	0
SANTA BARBARA	183	2,937	0	0	0	0	1,345	1,586	0	6	0
MELBOURNE	183	4,091	0	0	0	0	2,441	1,650	0	0	0
SPRINGFIELD, MO	181	6,812	0	0	0	0	728	5,615	0	469	0
ASHVILLE	179	7,241	0	0	0	2	556	4,602	0	2,081	0
COLUMBUS, GA	172	5,941	0	0	0	0	11	5,929	0	0	1
BURLINGTON, VT	170	5,140	0	0	0	0	159	3,295	0	1,166	520
SCRANTON/SILKES BARRE	162	3,433	0	0	0	0	1,347	2,083	1	0	2
NEWPORT NEWS	161	4,566	0	0	0	4	828	2,519	0	1,215	0
FAYLTTEVILLE, NC	161	5,872	0	0	0	0	1,732	3,034	0	1,106	0
GRAND JUNCTION	159	3,881	0	0	0	185	1,102	822	0	1,772	0

TABLE A-1 (Continued)

	ENPLANE-MENTS (000)	DEPARTURES BY AIRCRAFT TYPE										
		TOTAL	WIDE BODY			REGULAR BODY			TURBOPROP		OTHER
			4 ENG	3 ENG	2 ENG	4 ENG	2 ENG	3 ENG	4 ENG	2 ENG	
FARGO	155	5,280	2	2	0	0	2,133	1,820	0	1,323	0
ROCHESTER, MN	152	6,387	1	1	0	0	2,506	2,045	0	1,834	0
RAPID CITY	149	5,324	0	0	0	0	4	4,586	0	734	0
GREAT FALLS	140	4,590	3	123	0	78	1,493	2,893	0	0	0
ERIE	140	3,549	0	0	0	0	74	3,469	0	4	2
FLINT	140	4,868	0	0	0	13	886	2,598	0	1,371	0
YOUNGSTOWN	138	4,096	0	0	0	21	849	2,677	0	153	396
BANGOR	138	2,750	0	0	0	0	1,781	969	0	0	0
BAKERSFIELD	137	3,247	0	0	0	0	256	2,991	0	0	0
DULUTH	136	6,028	0	0	0	0	4,749	1,279	0	0	0
GAINSVILLE	135	1,817	0	0	0	0	355	1,462	0	0	0
ASHLAND/HUNTINGTON	130	4,837	0	0	0	0	333	2,408	0	2,096	0
CASPER	129	4,204	0	0	0	0	25	3,501	0	678	0
CHAMPAIGN	129	4,962	0	0	0	0	0	3,377	0	1,585	0
BISMARK	128	5,038	0	0	0	0	1,534	1,780	0	1,438	286
KALAMAZOO	128	4,900	0	0	0	0	0	2,218	0	2,682	0
SPRINGFIELD, IL	127	5,735	0	0	0	0	0	4,277	0	1,458	0
MEDFORD	123	2,416	0	0	0	0	5	2,411	0	0	0
WATERLOO	119	5,882	0	0	0	0	0	3,477	0	2,405	0
MONROE	117	4,923	0	0	0	0	2,246	2,575	0	102	0
ELGIN	115	4,409	0	0	0	0	0	4,409	0	0	0
LAFAYETTE, LA	115	3,042	0	0	0	0	0	3,038	0	4	0
JOPLIN	113	3,954	0	0	0	0	0	1,542	0	2,412	0
MISSION	113	2,127	0	0	0	0	0	2,127	0	0	0
SOUIX CITY	113	7,567	0	0	0	0	0	4,678	0	2,889	0

TABLE A-1 (Continued)

	ENPLANE-MENTS (000)	DEPARTURES BY AIRCRAFT TYPE										
		TOTAL	WIDE BODY			REGULAR BODY			TURBOPROP		OTHER
			4 ENG	3 ENG	2 ENG	4 ENG	3 ENG	2 ENG	4 ENG	2 ENG	
GRAND FORKS	103	5,385	0	0	0	0	871	2,512	0	2,002	0
ACARTA/EUREKA	102	2,059	0	0	0	0	0	1,707	0	352	0
PASCO	100	2,954	0	0	0	0	0	2,954	0	0	0
MACON	98	2,185	0	0	0	0	10	2,175	0	0	0
WASSAU	98	4,593	0	0	0	0	0	3,216	0	1,377	0
FORT SMITH	93	6,510	0	0	0	0	1,425	970	0	4,115	0
IDAHO FALLS	92	2,453	0	0	0	0	0	2,453	0	0	0
GULFPORT	91	3,605	0	0	0	0	0	3,605	0	0	0
MUSKEGON	85	4,082	0	0	0	0	10	1,769	0	2,303	0
WILMINGTON, NC	85	4,718	0	0	0	0	345	1,910	0	2,463	0
TRAVERSE CITY	84	3,082	0	0	0	0	0	1,935	0	1,147	0
MYRTLE BEACH	83	3,634	0	0	0	0	0	1,812	0	1,822	0
MISSOULA	82	2,366	0	0	0	0	1,082	1,284	0	0	0
PANAMA CITY	78	3,439	0	0	0	0	533	2,906	0	0	0
BEAUMONT	75	2,288	0	0	0	0	571	1,714	0	3	0
BINGHAMPTON	73	2,579	0	0	0	0	32	1,220	0	1,327	0
DOTHAN	72	2,807	0	0	0	0	0	2,804	0	0	3
ELMIRA	71	2,956	0	0	0	0	13	1,228	0	1,715	0
ALEXANDRIA, LA	70	2,956	0	0	0	0	2,061	769	0	129	0
MINOT	70	2,813	0	0	0	0	0	1,796	0	719	298

TABLE A-1 (Continued)

	ENPLANEMENTS (000)	DEPARTURES BY AIRXRAFT TYPE									
			WIDE BODY			REGULAR BODY			TURBOPROP		
		TOTAL	4 ENG	3 ENG	2 ENG	4 ENG	3 ENG	2 ENG	4 ENG	2 ENG	OTHER
OSHKOSH	70	3,831	0	0	0	0	0	1,142	0	2,689	0
TOPEKA	67	4,180	0	0	0	0	0	1,836	0	2,344	0
ALBANY, GA	66	2,759	0	0	0	0	0	2,745	0	0	14
CHARLOTTESVILLE	66	3,216	0	0	0	0	327	1,007	0	1,882	0
COLUMBIA, MO	65	3,538	0	0	0	0	0	1,325	0	2,213	0
JOPLIN	65	3,954	0	0	0	0	0	1,542	0	2,412	0
ITHACA	65	3,018	0	0	0	0	5	985	0	2,028	0
BOZEMAN	64	2,247	0	0	0	0	924	1,320	0	1	2
POCATELLO	63	2,884	0	0	0	0	0	2,884	0	0	0
SMITH/REYNOLDS	61	4,859	0	0	0	0	686	1,754	0	2,419	0

TABLE A-2

SAMPLE STRATIFIED BY ENPLANEMENTS

PASSENGER RANGE	AIRPORTS	TOTAL	LARGE	3 ERB	2 ERB	2 ETP	COMMUTER	TOTAL ENPLANEMENTS (000)
350 plus	2	25,967	0	5,644	12,067	8,256	0	734
300-349	11	87,470	2,085	30,659	45,660	7,285	1,749	3,539
250-299	12	92,898	751	29,170	47,660	14,127	1,190	3,252
200-249	13	84,937	107	22,156	50,374	10,890	1,410	2,940
150-199	14	74,877	925	22,257	40,197	10,974	524	2,399
100-149	26	110,663	238	15,461	71,915	22,365	684	3,257
61-99	27	91,555	0	8,024	50,106	33,108	317	2,052
TOTAL	105	568,367	4,106	133,371	318,011	107,005	5,874	18,173

TABLE A-3

RELATIONSHIPS BETWEEN PASSENGERS AND SEATS

PASSENGER RANGE	AVERAGE ENPLANEMENTS	AVERAGE DEPARTURES	PASSENGERS PER DEPARTURE	SEATS PER DEPARTURE	PASSENGERS PER SEAT
350 plus	367,000	12,983	28.3	84.3	.34
300-349	321,700	7,952	40.5	98.0	.41
250-299	271,000	7,742	35.0	93.8	.37
200-249	226,150	6,534	34.6	92.2	.38
150-199	171,360	5,348	32.0	93.8	.34
100-149	125,300	4,256	29.4	86.9	.34
61-99	76,000	3,391	22.4	78.8	.28
AVERAGE	173,076	5,413	32.0	90.0	.355

TABLE A-4

LOCAL-TRUNK SPLIT FOR SAMPLE AIRPORTS

PASSENGE RANGE	AIRPORT SERVICE TOTAL	TRUNKS	LOCAL	MIXED	ENPLANEMENTS (000) TOTAL	TRUNKS	LOCAL
350 and More	2	0	0	2	734	118	616
300 - 349	11	3	1	7	3,539	2,544	995
250 - 299	12	1	0	11	3,252	2,101	1,151
200 - 249	13	2	1	10	2,940	2,086	854
150 - 199	14	1	1	12	2,399	1,380	1,019
100 - 149	26	2	13	11	3,257	1,162	2,095
61 - 99	27	1	17	9	2,052	369	1,683
TOTAL	105	10	33	62	18,173	9,760	8,413